Ground-Based Cloud Measurements Used to Evaluate the Simulation of Arctic Clouds in CCSM4

Research Highlight

Arctic climate is changing at a rate exceeding that of other regions. Prediction of the future rate of change of Arctic climatic processes requires the use of sophisticated earth-system models. Many of these models have recently completed simulations for the upcoming fifth version of the Coupled Model Intercomparison Project (CMIP5). In order to provide a reference for the global and Arctic climate communities on the performance of one of these models, 20th-century simulations from the Community Climate System Model, version 4 (CCSM4), were evaluated against a range of reanalysis and measurement products. In addition to assessments of surface air temperature, sea level pressure, lower tropospheric stability, and precipitation and evaporation, a major component of this work involved evaluation of the model's clouds. This evaluation relied heavily upon measurements obtained at the Department of Energy's ARM Facility site at Barrow, Alaska; at Eureka, Canada; and over the Beaufort Sea during the Surface Heat Budget of the Arctic (SHEBA) campaign. Evaluated were properties such as cloud occurrence, cloud phase, and cloud water path.

Measurements included in this analysis come from lidars, radars, and microwave radiometers. From these measurements, cloud occurrence, cloud water path, and cloud phase were derived. These estimates were used to evaluate simulated clouds at both the specific measurement locations and in an Arctic-wide sense. In general, simulated Arctic-wide cloud occurrence was found to be much too low for most of the year. With the exception of late summer months, simulated cloud occurrences of around 30% compared to observational estimates of 50–70 %. Despite this under-prediction of cloud frequency, the all-sky liquid water path (essentially liquid amount for both cloudy and clear conditions) was found to be too high. This indicates that the clouds that did occur were generally too thick.

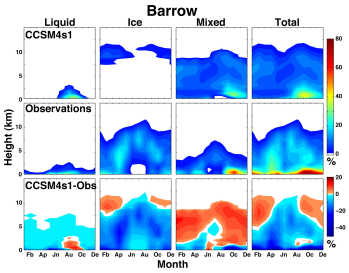
In addition to the evaluation of cloud occurrence and water path, cloud phase was also analyzed. Simulated ice water paths were found to be too low, particularly in summer months. This was found to be the result of temperature-dependent phase partitioning employed by the model. An evaluation of cloud phase at the three measurement sites indicated that simulated ice clouds only occurred during winter months at high altitudes due to the temperature restrictions imposed upon their existence. This is in contrast to the observations, which indicated ice clouds at much lower altitudes, occurring throughout the year. Similar mismatches occurred between simulated and observed liquid and mixed-phase clouds.

DOE ARM observations, along with others, provide a point of validation for Arctic clouds simulated by CCSM4. Model cloud properties were demonstrated to vary from those observed. Specifically, simulated clouds were found to occur less frequently than those observed, were determined to have substantially larger liquid water paths when they did occur, and hydrometeor phases were found to be different than those observed due to temperature-dependent phase partitioning. These differences resulted in discrepancies between simulated atmospheric energy budgets and those from reanalyses and observations. This difference has potentially large consequences on the melting rates of surface snow and ice as well as sea ice. In general, a transition away from temperature-dependent cloud phase partitioning is recommended, along with continued efforts to improve cloud micro- and macrophysics.

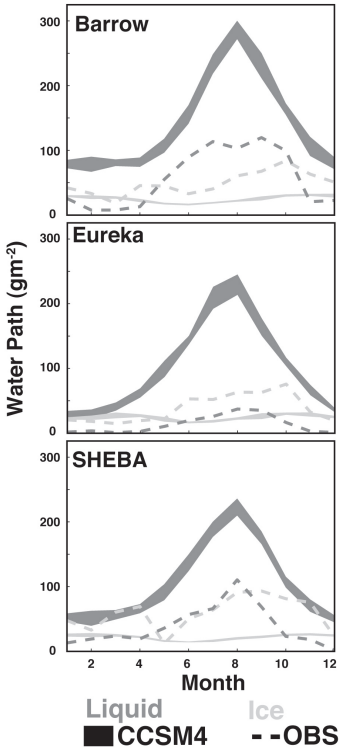
Reference(s)

de Boer G, W Chapman, JE Kay, B Medeiros, MD Shupe, S Vavrus, and JE Walsh. 2011. "A characterization of the present-day Arctic atmosphere in CCSM4." Journal of Climate, 25(8), doi:10.1175/JCLI-D-11-00228.1.

Contributors



Time-height cross-sections of simulated (top) and observed (second row) cloud phase at Barrow, Alaska. The difference between the frequencies of occurrence of each phase is indicated in the third row.



Monthly distributions of liquid (dark) and ice (light) water paths at Barrow (top), Eureka (center), and SHEBA (bottom). The dashed lines indicate the observed values, while the shading represents the ensemble spread in CCSM4 results.

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Working Group(s)
Cloud Life Cycle